NASA TECH BRIEF

Effect of Wall Roughness on Liquid Oscillations Damping in Rectangular Tanks

The dynamic behavior of contained liquids is currently the subject of intensive study. The purpose of this investigation was to determine the effect of wall roughness within tanks, specifically as a source of damping. Increasing the wall skin friction would be expected to increase the rate of damping, and earlier studies of damping in smooth-wall tanks confirmed this assumption.

To accomplish the present investigation, tests were conducted in two rectangular glass tanks using silicon carbide grit bonded to the tank walls to produce roughness. Testing procedures included the effects of roughness height, roughness location, roughness at various values, and an in-depth discussion of flow regimes and the mechanism of damping because of roughness. Additional investigation included amplitude decay, effects of wetted perimeters on damping, and Reynolds number and boundary layer thickness data. The study of the effectiveness of wall roughness for damping liquid oscillations in rectangular tanks produced the following results: (1) The value of log decrement of damping, δ, increased in a nearly linear fashion as the roughness height was increased. With roughness of which the height was 0.427% of the tank length covering 8.9% of the wetted wall area, δ was 65% greater than the smooth-wall value: (2) Roughness near the liquid surface was more effective in damping liquid oscillations than roughness deep in the tank. There was a sharp increase in damping corresponding to wiping of the roughness by the surface edge during decay. Maximum damping was produced by a particular roughness strip when the strip was at the maximum depth at which the surface edge wiped the roughness throughout decay of the

oscillation. Narrow strips of roughness (3.6% of the wetted wall area) in contact with the liquid surface edge during decay were found to produce 75% as much damping as roughness covering the entire end walls of the tank (36% of the wetted wall area): (3) The damping was found to increase with decreasing values of $L^{3/2}g^{1/2}/v$, but the increment of damping because of wall roughness remained nearly constant through most of the $L^{3/2}g^{1/2}/v$ range (L = tank length in cm; g = acceleration in the direction tending to hold the liquid in the tank bottom, in cm/sec^2; and v = kinematic viscosity of test liquid in cm^2/sec). The increment of δ because of a particular wall roughness configuration was 34.5% of the total at $L^{3/2}g^{1/2}/v$ = 650,000 and was only 13.5% of the total δ at $L^{3/2}g^{1/2}/v$ = 27,000. (4) A formula was constructed to fit the smooth-wall damping data through the range of values of $L^{3/2}g^{1/2}/v$ investigated by multiplying Keulegan's equation for smooth-wall damping by an empirical constant. An expression formed by adding a term dependent on roughness height relative to tank length to the above formula gave a fair representation of the effect of roughness height on damping through a range of $L^{3/2}g^{1/2}/v$ values for a particular roughness configuration. (5) Reynolds number and boundary layer thickness calculations indicated that the test roughness should have little effect on viscous damping. Other calculations showed that the damping because of roughness could be produced by surface tension acting on the roughness-height-dependent wetted perimeter through a changing contact angle.

This information may be of interest to designers of tanks and containers, especially truck, railroad, and marine tankers.

Note:

Requests for further information may be directed to:
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No patent action is contemplated by NASA.

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